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COMPOSITION OF THE RHIZOME, STEM, AND LEAF OF SOME HORTICULTURAL FORMS OF CANNA IN RELATION TO THEIR POSSIBLE USE

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CONTENTS

	Page
Introduction	1
Purpose of the work	1
Material and methods	2
Source of material	2
Cultural methods	3
Methods of sampling	3
Analytical methods	5
Compostion of rhizomes of edible group	5
Relation to weather conditions	6
Variations in clones	9
Composition of rhizomes of ornamental varieties	9
Composition of different parts of the plant	11
Rhizomes	14
Stalk	14
Composition of different parts of the plant—Continued.	
Leaves	14
Discussion	15
Yields	15
Cooking tests	17
Color	18
Texture	18
Flavor	18
Canning tests	18
Discussion	19
Summary	20
Literature cited	21

INTRODUCTION

Botanical forms of the genus *Canna* have long been cultivated for their decorative foliage and showy flowers, and horticultural literature (*2*)[1] contains many reports describing these forms. To a limited extent certain forms of canna, particularly *Canna edulis* Ker., have been used as food for man and animals, but apparently they have failed to become of great economic importance in any part of the world as a food product. In the American Tropics, according to Sturtevant (*5*), the rootstocks or rhizomes are rasped and the material is then washed and strained, thus obtaining a product that constitutes one of the classes of arrowroot known as "tous les mois."

The canna is used to a considerable extent in the Hawaiian Islands for the commercial production of starch. For a number of years the Hawaiian Agricultural Experiment Station (*4, 6, 10, 11*) has carried on rather extensive studies concerned with the culture, physiology, and composition of the plant. In Australia considerable attention (*8, 12*) has been given to its usefulness as a starch producer, and Lutz (*7*) has described the occurrence of a gum in the tissues of the rhizome. However, very little has been published upon its chemical composition and characteristics when grown in temperate regions.

PURPOSE OF THE WORK

These studies were undertaken primarily for the purpose of obtaining records of the chemical composition of the plant as grown in temperate regions and of determining the range of difference occurring

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[1] Italic numbers in parentheses refer to Literature Cited, p. 21.

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in different botanical forms, as well as the seasonal variations in composition in the individual forms. Two rather distinct botanical types have been analyzed—the edible and the ornamental. The work was carried on over a period of 6 years. The rhizomes of one edible variety were analyzed each year for 6 years, and the others were analyzed each year for 2 to 4 years. Data from the ornamental varieties have been obtained for 1 to 4 years each.

Data on the composition of the different parts of the plant, particularly the leaf, stem, and rhizome were also obtained. In addition, the desirable and undesirable characteristics of the rhizome as a food product were considered. Several varieties of both ornamental and edible groups have been used in these tests. No tests concerned with the use of the plant for the production of starch have been made except insofar as the studies of composition relate to the utilization of the plant.

No special study has been made in these investigations to determine the best cultural practices, but a few observations of the behavior of the different botanical forms and the records of yields seem worthy of presentation.

The results herein presented should be considered as a preliminary survey to a more thorough study of the value of the canna for various specific uses.

MATERIAL AND METHODS

SOURCE OF MATERIAL

The species (*Canna edulis* Ker.) is quite variable in many characteristics, such as color of the foliage, height of the stem, earliness of flowering, seed production, and size, shape, and composition of the rhizome. There are few or no named varieties, but there are a number of distinct clones that have been widely distributed over various parts of the world. Many of these variants have attractive foliage which has led to their preservation and use as ornamentals. The first form obtained was an early flowering clone frequently cultivated about Washington, D. C., for its ornamental bronze foliage. It was obtained in 1928 from a local seedsman and was grown in quantity every year during the entire period of the experimental work. The writers have been unable to determine its origin, and it has been designated as Early Flowering No. 40 in this report.

In 1930 a quantity of seed was saved from this clone and planted in the spring of 1931, the purpose being to gain some idea as to the variability that might be expected and the consequent possibility of obtaining types particularly adapted to temperate regions. The planting from which the seed was obtained was well isolated, so that there was little possibility that the resulting seedlings could have been due to pollination by foreign pollen. It was immediately evident that the clone was a heterozygous form, for the seedlings varied rather strikingly in color of foliage, height of stalk, earliness of flowering, and size, shape, and yield of rhizomes. From the more than 200 seedlings, 10 were selected for further study and analysis, and because of their variability in the characters above mentioned. Chemical analyses and cooking tests were made with these during the years 1932 and 1933. In this circular these seedlings will be referred to by number.

In 1929 there was obtained from the Hawaiian Agricultural Experiment Station the variety generally grown in the islands for the production of starch, and also a distinct form designated as Java canna. A clone obtained from seedsmen in this country listed as "Canna robusta" proved to be identical with the Java clone; also several seedlings from the Hawaiian Station, which were being tested for their value as starch producers, were obtained. These forms have been listed in Inventory 99 (*13*) and include P. I. Nos. 80382–80387. Four of these have been analyzed during 1 or more years. P. I. No. 80386 has been designated as Hawaiian clone, No. 80387 as Java clone, and Nos. 80382 and 80384 as Hawaiian seedlings.

Among others, seed of a form of *Canna edulis* was obtained from the Union of Soviet Socialist Republics in 1931, which proved to be quite distinct from all other forms previously secured. Rhizomes of this form (P. I. No. 92307) were analyzed and studied during the years 1931–33. It has been designated in this report as the Russian clone.

Examination of the vegetative and fruiting structures of all the above forms shows that they belong to the species *Canna edulis* or are hybrid forms approaching closely the *C. edulis* type.

The ornamental varieties were all obtained from seedsmen in the United States. These are widely grown garden forms obtained by breeders through the hybridization of several species. They are very distinct in a number of characters from the *edulis* group. Chief among these differentiating characters are the very much smaller, more fibrous rhizomes and the larger, more brilliantly colored flowers. The rhizomes of each of these varieties, which were grown from 1928 to 1934, have been analyzed in 1 or more years during this period. The ornamental group includes 20 varieties varying widely in color of flowers and other characteristics.

CULTURAL METHODS

The material was grown at the Arlington Experiment Farm, Arlington, Va. The soil was a deep medium sandy loam formed by the dredging operations along the Potomac River. The water table was 4 to 6 feet below the surface, but the soil was well drained, so that the moisture conditions were favorable for the growth of canna.

The seed stock or rhizomes were planted in rows 3.3 feet apart and were spaced 1½ to 2 feet in the row. The planting was done as early in the season as weather conditions permitted, which in these years was between April 10 and April 20. The plants made slow growth at first, but grew very vigorously and stooled abundantly during the long, hot days of July and August. Clean cultivation was employed until the plants were large enough to prevent other growth, which was about August 1. No fertilizer or manure was applied to the crop at any time, but the soil had received manure or fertilizer in preceding years. The height the plants finally attained varied greatly with the variety and the seasonal conditions, but plants of the edible group generally attained 7 to 10 feet.

METHODS OF SAMPLING

Two series of samples were taken for chemical analysis. The first series consisted of rhizomes alone. In these samples the older mature rootstocks were not included, because the material was to be considered chiefly from the standpoint of its use as a table product for which the older mature rootstocks appeared to be much less desirable. The methods of sampling, therefore, differed considerably from those employed at the stations in Hawaii (*4, 6, 11*) and Puerto Rico (*3*) where the mature rootstocks were generally employed. However, it should be stated that the portion of the underground parts consisting of old, mature rootstocks was generally small. In most of the varieties here studied the seasonal conditions during the early part of the fall favored the formation of a large number of rhizomes. These rhizomes were outgrowths from the vigorous plants and were apparently awaiting conditions favorable for growth into new plants. The material sampled consequently consisted of those parts of the underground portion which would have been suitable for planting the following year.

In this first series samples of the rhizomes of all the different forms were taken at the end of each season, immediately after the crop had been dug. Several bushels were brought into the laboratory; from these a number of rhizomes were selected and a representative chemical sample was taken by slicing off longitudinal segments, cutting the slices into small pieces and mixing them thoroughly, after which duplicate 100-g samples were weighed out. To the samples 95-percent alcohol was added in sufficient quantity to make the alcoholic content 75 to 80 percent. The samples were placed in quart glass jars and heated in a water bath until the alcohol came to a vigorous boil, when the jars were removed and the lids clamped down to seal them. In this way most of the air was excluded from the samples during storage previous to extraction and analysis.

In the second series, the samples consisted of different parts of the entire plant. These were taken as late in the season as appeared possible without danger of having the foliage injured by frost. In preparing the samples, stalks, foliage, and rhizomes were each subdivided into three parts. The rhizomes were cut transversely into three portions of approximately equal length, designated as apical, middle, and basal thirds. These parts were sampled and preserved separately in alcohol as just described.

The leaves were separated into three groups; the oldest or basal leaves were put in one group, the youngest or the leaves at the top of the stalk were put into another, and those intermediate in age and position into a third. The samples of leaves included the midrib but not the leaf sheath. The stalks were divided into three parts: The basal third was put into one group, the apical third into another, and the middle portion into a third. In the samples of the stalks the leaf sheath, which is closely attached to the stem, was included. No record of the exact age of each stalk was kept; consequently there was some variation in the age of the different stalks included in the samples. However, the greater part of the material appeared to be of similar age and characteristic of the variety at the time the samples were taken. As a large number of stalks were used for each sample, it is believed that the samples were strictly comparable with each other and representative of the variety and of the specified part of the plant. Two to four kilograms of the material were chopped very finely in a rotary slicer and thoroughly mixed; then duplicate 100-g samples were weighed out, and all samples were preserved in alcohol as already described.

ANALYTICAL METHODS

To separate the alcohol-soluble from the alcohol-insoluble material the samples were extracted by decanting the alcohol in which they had been preserved, filtering it through an extraction thimble, adding to the preserved sample more 95-percent alcohol, and grinding the material with a pestle. The added alcohol was poured through the extraction thimble and another quantity was added which was also poured through the extraction cup. The residual material was transferred to the extraction cup, placed in a Soxhlet apparatus and extracted 8 hours with 95-percent alcohol. The extracts were combined, made up to volume, and aliquot portions taken for the determination of the soluble solids, sugars, acidity, tannins, and nitrate nitrogen. The residue was dried and weighed, and portions were used for the determination of acid-hydrolyzable polysaccharides.

The sugars were determined by the volumetric permanganate modification of the Munson-Walker method as given in the Methods of the Association of Official Agricultural Chemists (*1*).

The acid-hydrolyzable polysaccharides were determined by hydrolysis with hydrochloric acid as prescribed in the official methods.

Total astringency was determined by titration with 0.05 N potassium permanganate with indigo carmine as indicator.

Titratable acidity was determined by titration with N/10 sodium hydroxide using phenolphthalein as indicator.

Total nitrogen was determined by the Gunning-Arnold method as modified by Ranker (*9*) to include nitrate nitrogen.

Nitrate nitrogen was determined by the ferrous chloride method as recommended in the Methods of the Association of Official Agricultural Chemists (*1*) for the estimation of nitrates in meats.

COMPOSITION OF RHIZOMES OF EDIBLE GROUP

The composition of the rhizomes of the edible group is shown in table 1. It is obvious that, as compared with many fruit and vegetable products used as food materials, the rhizome of the canna is rather low in total nitrogen, total sugar, and acid content, while it is medium to high in total solids and acid-hydrolyzable polysaccharides, total astringency or tannin, and nitrate nitrogen content.

TABLE 1.—*Chemical composition of the rhizomes of different clones of Canna edulis, 1928–33*

Clone	Date of harvest	Soluble solids	Insoluble solids	Total solids	Reducing sugars	Nonreducing sugars	Total sugar	Acidity as citric acid	Total astringency	Nitrate nitrogen	Total nitrogen	Acid-hydrolyzable polysaccharides
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Early Flowering No. 40	Oct. 30, 1928	3.12	13.39	16.51	1.23	1.30	2.53	0.102	0.186	0.0051	0.184	10.97
	Oct. 24, 1929	2.36	12.23	14.59	1.62	.18	1.80	.124	.126	.0166	.195	9.24
	Oct. 25, 1930	2.57	13.26	15.83	.78	1.07	1.85	.081	.297	.0145	.161	9.94
	Oct. 26, 1931	2.72	14.81	17.53	.83	.74	1.57	.115	.241	.0165	.219	11.48
	Oct. 18, 1932	2.92	10.74	13.66	1.90	.68	2.58	.107	.220	.0138	.160	8.01
	Nov. 12, 1933	3.62	13.54	17.16	1.81	.43	2.24	.147	.241	.0076	.184	12.17

TABLE 1.—*Chemical composition of the rhizomes of different clones of Canna edulis, 1928–33*—Continued

Clone	Date of harvest	Soluble solids	Insoluble solids	Total solids	Reducing sugars	Nonreducing sugars	Total sugar	Acidity as citric acid	Total astringency	Nitrate nitrogen	Total nitrogen	Acid-hydrolyzable polysaccharides
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Hawaiian, P. I. 80386	Oct. 24, 1929	2.62	10.03	12.65	0.80	0.41	1.21	0.167	0.105	0.0229	0.158	7.30
	Oct. 25, 1930	2.82	10.25	13.07	1.28	.21	1.49	.114	.148	.0338	.158	7.59
	Oct. 26, 1931	4.12	9.53	13.65	1.02	.82	1.84	.168	.157	.0124	.148	7.71
	Oct. 18, 1932	3.38	9.62	13.00	1.64	.34	1.98	.154	.132	.0102	.137	7.32
	Nov. 12, 1933	2.84	10.28	13.12	.97	.32	1.29	.154	.170	.0036	.170	7.96
Java, P. I. 80387	Oct. 25, 1930	2.26	18.29	20.55	.23	1.00	1.23	.064	.105	.0128	.200	14.53
	Oct. 26, 1931	2.68	13.07	15.75	-----	-----	-----	.141	.107	.0091	.220	10.40
	Oct. 17, 1932	4.16	10.34	14.50	1.74	1.17	2.91	.109	.130	.0110	.175	8.26
	Nov. 12, 1933	2.52	18.45	20.97	.81	.82	1.63	.141	.130	.0026	.156	14.62
Russian, P. I. 92307	Oct. 26, 1931	2.38	9.35	11.73	-----	-----	-----	.127	.256	.0269	.206	6.00
	Oct. 18, 1932	2.76	7.07	9.83	1.44	.18	1.62	.134	.370	.0139	.129	4.89
	Nov. 12, 1933	2.56	11.05	13.61	1.02	.42	1.44	.127	.406	.0070	.178	7.09
Hawaiian seedling, P. I. 80384.	Oct. 25, 1930	1.82	21.52	23.34	.12	.40	.52	.114	.193	.0152	.239	17.99
P. I. 80382	do	4.42	15.87	20.29	1.57	.44	2.01	.168	.227	.0157	.261	12.83
Seedling No. 1	Oct. 18, 1932	2.36	14.88	17.24	.56	.37	.93	.127	.216	.0150	.248	11.61
	Nov. 12, 1933	2.72	12.79	15.51	1.22	.38	1.60	.117	.181	.0192	.192	9.57
Seedling No. 2	Oct. 18, 1932	3.92	5.24	9.16	1.95	.75	2.70	.067	.148	.0126	.101	3.41
	Nov. 12, 1933	3.60	9.91	13.51	1.95	.51	2.46	.124	.260	.0048	.132	7.29
Seedling No. 3	Oct. 18, 1932	2.04	11.46	13.50	2.00	.40	2.40	.094	.185	.0175	.153	8.50
	Nov. 12, 1933	3.24	13.57	17.81	1.55	.58	2.13	.127	.224	.0070	.174	10.26
Seedling No. 4	Oct. 18, 1932	3.60	9.67	13.27	1.53	.62	2.15	.121	.317	.0081	.165	7.42
	Nov. 12, 1933	3.80	14.79	18.59	1.51	.07	1.58	.174	.386	.0015	.197	10.80
Seedling No. 5	Oct. 18, 1932	3.48	9.43	12.91	1.37	.81	2.18	.114	.256	.0073	.258	7.12
	Nov. 12, 1933	3.60	14.27	17.87	1.63	.85	2.48	.147	.278	.0017	.269	11.08
Seedling No. 7	Oct. 18, 1932	2.56	15.58	18.14	1.83	.47	2.30	.114	.162	.0153	.196	13.71
	Nov. 12, 1933	3.12	12.75	15.87	1.34	.38	1.72	.161	.244	.0040	.152	11.79
Seedling No. 10	Oct. 18, 1932	4.07	9.08	13.15	2.13	.79	2.92	.074	.122	.0085	.151	4.79
	Nov. 12, 1933	4.00	10.61	14.61	2.70	.24	2.94	.077	.212	.0029	.142	7.29
Seedling No. 11	Oct. 18, 1932	3.22	12.13	15.35	1.74	.41	2.15	.083	.141	.0172	.164	9.49
	Nov. 12, 1933	4.08	10.42	14.50	2.20	.63	2.83	.121	.190	.0176	.153	7.74
Seedling No. 15	Oct. 18, 1932	3.22	13.40	16.62	1.45	.61	2.06	.127	.332	.0178	.177	11.32
	Nov. 12, 1933	3.04	16.57	19.61	1.14	.46	1.60	.141	.414	.0014	.225	12.34
Seedling No. 31	Oct. 18, 1932	3.50	7.86	11.36	1.83	.70	2.53	.110	.189	.0131	.168	5.76
	Nov. 12, 1933	2.52	13.21	15.73	.94	.44	1.38	.154	.222	.0017	.182	10.08

Rather significant quantities of nitrate nitrogen were generally present, though it was extremely variable in amount. In the rhizome of the Hawaiian clone, P. I. 80386, there was 0.0338 percent in 1930 and 0.0036 in 1933. In the latter year the percentage was generally low in all clones. The variations are apparently due to the differences in the amount of nitrate nitrogen in the soil and to climatic conditions that favor or retard its synthesis into protein.

It may be noted that the content of acid-hydrolyzable polysaccharides indicates that the starch content of the Washington material is much lower than in that grown in Puerto Rico (*3*) and the Hawaiian Islands (*4, 6, 10, 11*). At these stations a starch content as high as 19 to 22 percent has been found. The total solids are also much lower than those generally found in material grown in Hawaii. The results are more nearly like those found by Ripperton (*10*) for certain young or immature rootstocks. The sugar content is generally that characteristic of immature material, being higher in reducing and lower in nonreducing sugar than for the mature material.

RELATION TO WEATHER CONDITIONS

There were very great variations in the composition of the rhizomes of all forms from year to year, particularly in the amount of total solids and acid-hydrolyzable polysaccharides. A great many variable factors probably combine to cause the differences. It might be expected that the influence of climatic factors would be apparent at once. Table 2 gives the total monthly rainfall for Washington and the average monthly temperature for July, August, September, and October, with the monthly and cumulative departures from normal, for the period 1928–33. As the material was generally harvested in October, it is doubtful whether variations in rainfall for this month are of much importance, but the temperature may be a factor through its influence on the time of the first killing frost. After careful examination of the results, it is apparent that there are many variations in the composition not directly attributable to differences in rainfall or temperature. For example, 1930 had the lowest total rainfall and the highest average temperature for July, August, and September, but the composition of the plants grown during this year was neither the highest nor the lowest, but was somewhat above the general average. The crops of 1929 and 1932 were generally lower in total solids and acid-hydrolyzable polysaccharides than the other years, and the total and reducing sugars were more often higher than lower than the average in these years. This was associated in both years with a deficiency in rainfall in July and August, followed by excess moisture in September and October. The results of 1933 were generally high, which is associated with an excess of rainfall in July and August followed by slight deficiencies in September and October. The records of the amount of sunshine for the period are not presented, but an examination of these records fails to show any very close correlation between the amount of sunshine and the composition of the material.

Table 2.—*Total monthly rainfall and the average temperature at Washington, D. C., for July, August, September, and October, 1928–33, with departures from normal in parentheses*

Year	Rainfall and departure from normal				Total and departure from normal for period
	July	August	September	October	
	Inches	*Inches*	*Inches*	*Inches*	*Inches*
1928	2.17(−2.54)	14.41(+10.40)	4.29(+1.05)	0.67(−2.17)	21.54(+6.74)
1929	1.29(−3.42)	1.30(−2.71)	4.32(+1.08)	4.82(+1.98)	11.73(−3.07)
1930	2.30(−2.41)	0.62(−3.39)	0.76(−2.48)	0.28(−2.56)	3.96(−10.84)
1931	4.23(−0.48)	5.92(+1.91)	2.79(−0.45)	1.28(−1.56)	14.22(−0.58)
1932	2.43(−2.28)	1.36(−2.65)	4.24(+1.00)	7.40(+4.56)	15.43(+0.63)
1933	6.71(+2.00)	9.91(+5.90)	2.62(−0.62)	2.56(−0.28)	21.80(+7.00)

Year	Mean monthly temperature and departure from normal				Mean temperature and departure from normal for period
	July	August	September	October	
	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
1928	78.2(+1.5)	77.0(+2.0)	64.9(−3.2)	59.9(+2.5)	70.0(+0.7)
1929	76.9(+0.2)	74.4(−0.6)	70.2(+2.1)	55.6(−1.8)	69.3(+0.0)
1930	80.4(+3.7)	76.8(+1.8)	76.1(+8.0)	56.2(−1.2)	72.4(+3.1)
1931	79.6(+2.9)	75.6(+0.6)	74.1(+6.0)	61.0(+3.8)	72.6(+3.3)
1932	77.4(+0.7)	77.8(+2.8)	70.3(+2.2)	58.0(+0.6)	70.9(+1.6)
1933	76.1(−0.6)	76.0(+1.0)	71.8(+3.7)	56.5(−0.9)	70.1(+0.8)

Ripperton (*10*) has shown that the composition of the rhizome depends upon its degree of maturity, and it is readily observable that the plant makes its growth and stools more or less in cycles. Irregularities in the weather conditions to a large extent control the occurrence of these cycles. A newly formed rhizome will grow immediately and form a stalk if conditions are favorable, but if the soil is a little dry it may enter into a period of more or less suppressed growth during which the carbohydrates may accumulate in the rhizome, provided the conditions adverse to growth are not severe enough to injure the foliage. It is probable that the dry periods in 1929 and 1932 followed by wet periods caused the formation of a late crop of rhizomes that did not have time to mature to the extent that normally occurred in other years. It also seems likely that the abundant moisture in July and August 1933 favored a good growth of foliage and the setting of an early crop of rhizomes which were permitted to accumulate starch during the much drier period of September and October. It appears then that the composition of the rhizomes will depend upon the length of time they have had to accumulate carbohydrates since their development began, or upon their stage of maturity, and upon the character of the weather during this time. The complexity of the weather cycles, the possible differences in response of varieties to these cycles, and especially the fact that the age of individual rhizomes varies widely and cannot be known, make it impossible to account for all the variations that occurred in these samples.

In just what manner weather conditions may have influenced the content of total nitrogen is not clear. There was a tendency for its content to be higher in 1933 than in 1932; however, as already pointed out, there was a tendency for the total solids to be higher in 1933 than in 1932, and if the content of total nitrogen is calculated on the dry-weight basis, it is found that the results were generally higher in 1932 than in 1933.

The content of acids and total astringency were likewise higher in 1933 than in 1932 and appeared to be associated to a considerable extent with the higher solids of 1933. It is probable that the same factors that cause the variation in solids influenced the accumulation of acids and tannins.

There seems to be no relationship between the variations in the weather conditions and those in the sugar content. Also, the sugar content varies quite independently of the other constituents.

In conclusion, it may again be stated that the variations that occur are due in considerable part to the stage of maturity of the rhizomes at the time of harvest.

It should be pointed out also that the water table was only a few feet below the surface, and that consequently the plants did not suffer from drought in periods of low rainfall, with the possible exception of 1930, as would have been the case on higher ground. Furthermore, the plants were grown in slightly different locations each year, so that the soil varied somewhat in its texture and other characteristics from season to season. So many factors were unknown or not under control that it is not surprising that the correlation of composition with weather conditions appears poor.

VARIATIONS IN CLONES

It is apparent that considerable variations occur in different clones. It so happened that the seedlings were analyzed in 1932, a year in which the results were generally low, and in 1933, when they were frequently high. Therefore extreme differences might be expected in the results for the 2 years.

The rhizomes of one of the clones from the Hawaiian Islands, P. I. 80384, had 23.34 percent of total solids and 17.99 percent of acid hydrolyzable polysaccharides. This was the highest record of any clone for any year, but unfortunately only 1 year's results were obtained. Seedling No. 2 of the Early Flowering No. 40 clone had an average of 11.33 percent total solids and 5.35 percent acid-hydrolyzable polysaccharides, which was the lowest average result obtained for any form. Of the clones analyzed for 3 years or more, the Java clone or "Canna robusta" appears to be on the average the highest in solids and acid-hydrolyzable polysaccharides, although in 1932 the results were quite low. The clone with the next highest average was the Early Flowering No. 40, while the Russian clone is lowest of those being compared.

Seedling No. 2, as stated above, gave very low readings, but Nos. 7 and 15 gave high ones. The results obtained for these seedlings indicate that there is a great variation in the composition of different clones, and points to the possibility of obtaining forms having a high starch content and better adaptation to growth for starch production in temperate regions than those in existence at the present time.

The total astringency varied considerably in different clones. The Russian clone, seedling Nos. 4 and 15, were notably higher than the others. This seems to be associated with an intense browning of the tissues, which occurs after wounding and exposure to the air.

COMPOSITION OF RHIZOMES OF ORNAMENTAL VARIETIES

The composition of the rhizomes of the ornamental varieties is shown in table 3. These varieties appear to be somewhat less variable among themselves and less variable from year to year in their solids content than those of the edible group, though rather large variations do occur.

TABLE 3.—*Chemical composition of the rhizomes of some ornamental varieties of canna, 1927–33*

Variety	Year of harvest	Soluble solids	Insoluble solids	Total solids	Reducing sugar	Nonreducing sugar	Total sugar	Acidity as citric acid	Total astringency	Nitrate nitrogen	Total nitrogen	Acid-hydrolyzable polysaccharides
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Allemania	1930	2.42	16.98	19.65	0.40	0.54	0.94	0.147	0.546	0.0362	0.197	11.54
Apricot	1932	3.08	8.21	11.29	.81	.52	1.33	.127	.544	.0484	.205	5.17
Copper Giant	1931	3.12	10.72	13.84	.57	.91	1.48	.154	.512	.0445	.274	7.13
	1932	2.68	11.17	13.85	.63	.85	1.48	.154	.601	.0118	.278	8.03
	1933	3.04	14.02	17.06	.64	.65	1.29	.174	.862	.0029	.155	9.74
Egandale	1931	2.72	8.97	11.69	.56	.60	1.16	.127	.504	.0801	.253	5.04
Eureka	1930	2.82	10.25	13.07	.56	.38	.94	.154	.955	.0335	.256	6.35
	1933	3.16	10.28	13.44	1.13	.36	1.49	.168	1.026	.0219	.187	6.79

TABLE 3.—*Chemical composition of the rhizomes of some ornamental varieties of canna, 1927–33*—Continued

Variety	Year of harvest	Soluble solids	Insoluble solids	Total solids	Reducing sugar	Nonreducing sugar	Total sugar	Acidity as citric acid	Total astringency	Nitrate nitrogen	Total nitrogen	Acid-hydrolyzable polysaccharides
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Favorite	1930	3.48	10.56	14.04	0.88	0.84	1.72	0.201	0.796	0.0462	0.257	6.31
Fiery Cross	1931	3.22	10.08	13.30	.50	1.10	1.60	.134	.298	.0359	.253	7.18
Gayety	1932	2.80	11.45	14.25	.47	.57	1.04	.174	.645	.0557	.298	8.01
General Merkel	1930	2.98	10.67	13.65	.81	.43	1.24	.168	.498	.0562	.236	11.30
Gladiator	1932	3.44	6.98	10.42	.80	.82	1.62	.188	.559	.0529	.207	5.43
Hungaria	1931	3.68	9.51	13.19	1.10	1.10	2.20	.134	.317	.0802	.234	7.95
Indiana	1929	2.50	14.92	17.42	.41	.59	1.00	.107	.302	.0505	.239	11.00
	1930	3.14	12.02	15.16	1.47	.33	1.80	.137	.430	.0568	.205	8.98
	1931	2.62	11.55	14.17	.74	.37	1.11	.107	.216	.0790	.261	8.47
	1932	2.60	10.05	12.65	.66	.53	1.19	.074	.323	.0731	.245	7.02
	1933	3.28	10.66	13.94	1.44	.43	1.87	.147	.390	.0200	.163	7.94
King Humbert	1930	2.58	11.72	14.30	.46	.56	1.02	.134	.318	.0760	.242	8.06
	1931	2.34	10.40	12.74	.50	1.11	1.61	.134	.298	.0359	.253	7.18
	1932	3.04	10.23	13.27	.54	.75	1.29	.161	.588	.0689	.292	6.81
	1933	2.70	14.98	17.68	1.11	.80	1.91	.188	.458	.0278	.189	11.07
Mrs. Louis Cayeaux	1932	2.36	11.68	14.04	.31	.38	.69	.147	.567	.0303	.235	8.31
	1933	2.72	14.23	16.95	.84	.47	1.31	.188	.806	.0038	.190	9.90
Nokomis	1930	3.68	12.27	15.95	.93	.85	1.78	.181	1.203	.0458	.255	8.42
	1931	3.34	8.64	11.98	1.06	.99	2.05	.168	.640	.0406	.218	5.51
	1932	3.12	12.84	15.96	1.03	.84	1.87	.121	.607	.0821	.276	9.58
	1933	3.24	15.51	18.75	.87	.79	1.66	.215	1.074	.0301	.259	10.71
Orange Bedder	1931	2.68	9.25	11.93	.70	.55	1.25	.107	.332	.0650	.179	6.59
Pennsylvania	1929	2.60	14.43	17.03	.39	.71	1.10	.114	.292	.0505	.239	10.94
	1930	3.40	10.52	13.92	1.29	.41	1.70	.174	.493	.0409	.193	7.69
	1931	3.24	10.00	13.24	1.06	.93	1.99	.141	.292	.0408	.231	7.16
	1932	3.08	10.40	13.48	.80	.96	1.76	.134	.340	.0451	.259	7.32
	1933	3.04	15.66	18.70	1.30	.65	1.95	.127	.406	.0170	.198	11.74
Statue of Liberty	1930	3.48	8.95	12.43	1.44	.63	2.07	.134	.504	.0417	.214	5.88
	1931	3.28	9.28	12.56	1.35	.56	1.91	.134	.317	.0802	.234	6.36
	1932	2.84	8.58	11.42	1.11	.63	1.74	.121	.307	.0738	.193	6.05
	1933	3.64	12.51	16.15	2.07	.13	2.20	.154	.430	.0231	.239	8.14
The Ambassador	1930	3.28	12.94	16.22	.52	1.04	1.56	.154	.745	.0231	.298	9.15
	1931	3.32	9.57	12.89	.49	.94	1.43	.107	.302	.0612	.259	6.47
	1932	3.08	8.67	11.75	.39	.84	1.23	.201	.655	.0453	.223	5.91
	1933	4.04	9.92	13.96	1.81	.57	2.38	.161	.782	.0082	.187	6.75
The President	1930	3.22	13.51	16.73	.49	1.13	1.62	.154	.868	.0391	.231	9.28
	1931	2.98	10.35	13.33	.34	1.12	1.46	.154	.504	.0764	.283	7.90
	1932	3.00	9.97	12.97	.43	1.23	1.66	.161	.601	.0425	.202	7.21
	1933	2.80	17.39	20.19	.45	.97	1.42	.201	.878	.0065	.266	12.51

Of the varieties analyzed for 4 or more years, Statue of Liberty on the average appears to be the lowest in total solids and acid-hydrolyzable polysaccharides and The President the highest, though it is doubtful whether the differences are very significant. In these two varieties there is considerable difference in the shape, size, and character of growth of the rhizomes. The rhizome of the former is rather large, long, or spreading, while that of the latter is usually short and thick. It is not clear just why the solids content should be correlated with shape of the rhizomes. The other varieties are more or less intermediate in their solids content.

There was a tendency for the total solids and acid-hydrolyzable polysaccharides to be highest in 1933 and lowest in 1932 with the other years more or less intermediate. The behavior of the ornamental varieties with reference to the amounts of these constituents present in their rhizomes is thus similar to that of the edible group. These variations are probably due for the most part to differences in the maturity of the rhizomes at the time of harvest.

A very striking difference between this group and the edible group is its much higher percentage of total astringency in the rhizome. In the edible group, the values range from 0.105 to 0.414 percent with a mean of 0.215 percent, whereas in the ornamental group they range between 0.216 and 1.203 percent with a mean of 0.552 percent. There appear to be considerable differences in astringency between varieties of the ornamental group. Eureka, Nokomis, The President, and The Ambassador appear to be considerably higher in astringency than the varieties Statue of Liberty, Pennsylvania, King Humbert, and Indiana. This difference seems to be associated to a certain extent with the difference in the character of the growth, the first-named varieties having rather large, long rhizomes, while the latter group generally have rather short, compact rhizomes.

On the average, the total nitrogen was considerably higher in the rhizomes of the ornamental group than in those of the edible group, and there was also a tendency for the nitrate nitrogen and the acidity to be higher. Differences in the total nitrogen, total sugar, and acidity between the varieties of this group are rather irregular, and do not appear to be very significant. The nitrate nitrogen tends to be somewhat higher in Statue of Liberty, Pennsylvania, Indiana, and Nokomis varieties which, with the exception of Nokomis, have long spreading rhizomes.

Some of the variations that occurred were doubtless due to sampling error. Judging by the physical differences in the rhizome along its length from base to tip, it would be expected that there would be corresponding chemical differences. This made the selection of representative samples more difficult, and consequently there was more chance of sampling error than with material less variable in physical structure and habit of growth.

COMPOSITION OF DIFFERENT PARTS OF THE PLANT

Plants from three distinct clones of the edible group were used to determine the composition of the different parts of the plant. All produced large plants with luxuriant foliage but yielded very different quantities of rhizomes. The Early Flowering No. 40 clone made the greatest yield with the Java clone next, and the Hawaiian the poorest. The work was continued over two seasons and the samples were taken on October 16, 1931, and October 7, 1932. The method of separating the parts of the plant into different regions has already been described (p. 4). The results are shown in table 4.

TABLE 4.—*Chemical composition of different parts of plants of the edible group of canna, 1931–32*

Clone	Plant part	Soluble solids		Insoluble solids		Total solids		Total astringency		Nitrate nitrogen		Total nitrogen	
		1931	1932	1931	1932	1931	1932	1931	1932	1931	1932	1931	1932
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Hawaiian P. I. No. 80386	Young leaf blade	4.64	6.54	11.63	12.01	16.27	18.55	0.532	1.088	0.0008	0.0029	0.524	0.553
	Intermediate leaf blade	5.44	7.77	11.88	12.54	17.32	20.31	.537	.954	.0082	.0067	.517	.561
	Old leaf blade	5.33	5.97	12.07	10.14	17.40	16.11	.611	.708	.0160	.0163	.443	.460
	Top of stalk	3.60	4.00	4.23	4.21	7.83	8.21	.087	.118	.0183	.0590	.198	.190
	Middle of stalk	3.20	4.46	3.68	3.71	6.88	8.17	.080	.038	.0447	.0941	.189	.188
	Base of stalk	3.53	4.62	3.50	3.44	7.03	8.06	.027	.019	.0820	.0980	.184	.198
	Tip of rhizome	2.72	3.38	8.31	8.99	11.03	12.37	168	.132	.0145	.0102	.182	.167
	Middle of rhizome	2.95	3.49	8.56	9.93	11.51	13.42	.137	.118	.0217	.0164	.160	.160
	Base of rhizome	3.46	3.40	8.81	9.82	12.27	13.22	.174	.154	.0338	.0199	.178	.131
Java, P. I. No. 80387	Young leaf blade	5.07	6.25	13.43	12.81	18.50	19.06	.611	.939	.0026	.0077	.677	.646
	Intermediate leaf blade	4.95	7.74	13.85	13.14	18.80	20.84	.373	.780	.0066	.0124	.477	.581
	Old leaf blade	4.84	5.40	11.77	12.01	16.61	17.41	.440	.714	.0075	.0153	.428	.460
	Top of stalk	4.53	3.68	4.43	4.65	8.96	8.33	.048	.092	.0592	.0761	.192	.191
	Middle of stalk	4.03	4.06	4.31	4.09	8.34	8.15	.041	.038	.0692	.0890	.182	.197
	Base of stalk	5.05	4.40	3.18	3.50	8.23	7.90	.040	.036	.0728	.0991	.193	.195
	Entire rhizome	2.68	4.16	13.07	8.34	15.75	12.50	.107	.130	.0091	.0110	.160	.145
Early Flowering No. 40	Young leaf blade	5.95	7.23	14.40	15.61	20.39	22.84	.613	.981	.0019	.0055	.718	.774
	Intermediate leaf blade	5.02	6.28	12.70	15.47	17.72	21.75	.524	.919	.0025	.0038	.556	.672
	Old leaf blade	3.98	7.17	12.76	13.12	16.74	20.29	.505	.714	.0085	.0084	.459	.414
	Top of stalk	4.29	4.52	5.81	5.69	10.10	10.21	.064	.065	.0672	.0569	.198	.167
	Middle of stalk	4.11	4.68	4.50	5.20	8.61	9.88	.047	.049	.0713	.0695	.203	.178
	Base of stalk	3.69	4.82	5.10	4.43	8.79	9.25	.042	.040	.0782	.0760	.201	.179
	Tip of rhizome	2.42	2.64	9.10	8.80	11.52	11.44	.158	.286	.0049	.0100	.161	.186
	Middle of rhizome	2.04	2.68	17.14	14.29	19.18	16.97	.149	.231	.0164	.0167	.155	.160
	Base of rhizome	3.26	2.84	14.55	15.39	18.71	18.23	.238	.256	.0221	.0229	.151	.146

Clone	Plant part	Reducing sugar		Nonreducing sugar		Total sugar		Acid-hydrolyzable polysaccharides		Acidity as citric acid	
		1931	1932	1931	1932	1931	1932	1931	1932	1931	1932
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Hawaiian, P. I. No. 80386	Young leaf blade	0.35	0.88	1.26	1.94	1.61	2.82	2.68	3.04	0.210	0.177
	Intermediate leaf blade	.55	.93	1.43	2.02	1.98	2.95	2.70	2.78	.190	.130
	Old leaf blade	.50	1.06	.86	1.30	1.36	2.36	2.20	2.60	.190	.114
	Top of stalk	1.63	1.52	.42	.45	2.05	1.97	1.24	1.06	.092	.060
	Middle of stalk	2.27	1.86	.46	.52	2.73	2.38	1.11	1.06	.122	.034
	Base of stalk	1.66	2.15	.46	.40	2.12	2.55	.97	.97	.031	.027
	Tip of rhizome	.51	1.04	.48	.52	.99	1.56	5.42	7.32	.124	.154
	Middle of rhizome	.87	1.00	.45	.88	1.32	1.88	6.80	8.46	.110	.109
	Base of rhizome	1.18	1.44	.78	.94	1.96	2.38	7.02	8.04	.071	.086
Java, P. I. No. 80387	Young leaf blade	.53	.82	.96	1.56	1.49	2.38	3.04	3.08	.168	.124
	Intermediate leaf blade	.81	1.00	1.00	1.47	1.81	2.47	2.48	2.75	.187	.105
	Old leaf blade	.78	1.00	.80	1.17	1.58	2.17	2.76	2.56	.152	.100
	Top of stalk	2.33	1.53	.63	.35	2.96	1.88	1.22	1.27	.036	.047
	Middle of stalk	2.37	1.95	.73	.35	3.10	2.30	1.18	1.21	.040	.023
	Base of stalk	2.94	2.40	.75	.26	3.69	2.66	1.21	.95	.031	.020
	Entire rhizome	1.06	1.74	1.10	1.17	2.16	2.91	10.40	7.26	.141	.109
Early Flowering No. 40	Young leaf blade	.59	.85	1.20	2.13	1.79	2.98	3.02	3.56	.193	.170
	Intermediate leaf blade	.70	.89	.93	2.12	1.63	3.01	2.66	3.39	.180	.513
	Old leaf blade	.73	1.12	.57	1.67	1.30	2.79	2.79	3.23	.125	.131
	Top of stalk	2.07	1.44	.80	.76	2.87	2.98	1.64	1.37	.067	.034
	Middle of stalk	2.15	2.45	.50	.56	2.65	3.01	1.18	1.33	.036	.027
	Base of stalk	1.93	2.02	.52	.54	2.45	2.79	1.38	1.07	.031	.020
	Tip of rhizome	.51	.79	.17	.54	.68	1.33	7.60	6.03	.101	.034
	Middle of rhizome	.44	.71	.47	.87	.91	1.58	13.40	10.71	.084	.027
	Base of rhizome	1.41	.99	.79	.91	2.20	1.90	12.82	11.71	.060	.020

RHIZOMES

The rhizomes were characterized by a rather variable content of total solids, insoluble solids, and acid-hydrolyzable polysaccharides with a low content of total nitrogen, total sugars, and acidity. Though not large in total amounts present, the content of nitrate nitrogen and total astringency is very significant. The composition is largely a result of the adaptation of the rhizome to the accumulation or the storage of starch in its tissues. From a comparison of the composition of the apical, middle, and basal portions of the rhizome, it is evident that the apical portion is generally lower in total solids, acid-hydrolyzable polysaccharides, nitrate nitrogen, and sugars, but higher in total nitrogen and acidity than the basal portion. This may be because the rhizomes were actively laying down starch at the time the samples were taken. To a certain extent, the deposition of starch was proceeding from the base towards the apex. The distribution of the total and the nitrate nitrogen may also be due to protein synthesis, which was occurring in the apical portion. The distribution of these constituents would probably be quite different in a mature rhizome or in one that has started into the growth of a new plant.

STALK

The stalk or stem of the plant is characterized by a high moisture content. Nearly all the other constituents are rather low, but nitrate nitrogen and total sugar, though not high in absolute amounts, are generally higher than in the rhizome. As is well known, the food materials elaborated in the leaves pass down through the conducting tissues of the leaf sheath and stem to the roots and storage organs. There is no indication of any great tendency to store sugars or other constituents in the stem of the plant.

The basal portion of the stalk is higher in its content of nitrate nitrogen and sugars but lower in its content of solids, acids, acid-hydrolyzable polysaccharides, and total astringency. A rather unusually large proportion of the total nitrogen was present as nitrate nitrogen, especially in the basal portion of the stalk, sometimes making up approximately one-half of the total. The sugars of the stem are predominantly reducing sugars and the soluble solids make up a larger proportion of the total solids than with the other parts of the plant examined. Therefore, the principal constituents appear to be substances being transported either to or from the leaves.

LEAVES

The foliage was characterized by a rather high content of total nitrogen, total solids, insoluble solids, and total astringency while the content of sugars, acids, and nitrate nitrogen was rather low. The high nitrogen content is due to the large amounts of protein and chlorophyll that are concerned in the photosynthetic processes of the plant. These are characteristics common to the leafy tissues of many other plants.

Total nitrogen, solids, total astringency, and titratable acidity are generally higher in the young or apical leaves than in the old or basal leaves, while the nitrate nitrogen and the reducing sugars were lower in the young than in the old leaves. The distribution of the total sugars was rather irregular, but was generally highest in the leaves intermediate in age. The nonreducing sugar or sucrose makes up a greater proportion of the total than the reducing sugar, which is a condition directly opposite to that in the stalk.

DISCUSSION

These results are generally in accord with those of Ripperton (*10*) who has investigated very thoroughly the composition of *Canna* in relation to its physiological behavior. However, due to differences in climatic conditions, the material used in these analyses shows unmistakable evidence of immaturity, especially the rhizomes. The composition of the foliage is more nearly like that grown in Hawaii than the rhizomes. For example, the dry matter for the leaves ranges between 17 and 22 percent (*10*), which is close to the range of variation found in these analyses.

The Hawaiian clone is the one generally grown in the islands for the manufacture of starch and as a forage plant. The other two clones used in the analyses of stalks and leaves are frequently grown in the eastern United States for their ornamental foliage. The similarity of the three clones indicates that they might all be used as forage crops. The results indicate that they all have considerable nutritive value, but the rather high content of astringent materials in the leaves might be a somewhat undesirable factor.

The large amounts of foliage with its relatively high nitrogen content and the vigorous growth indicate that when these plants are grown as ornamentals or as forage plants they are gross feeders and require large amounts of soil nutrients for use in the synthesis of the carbohydrates and proteins present.

YIELDS

In each of the years 1930, 1931, and 1932 a representative area, generally one-hundredth of an acre, of the plantings of a number of forms was harvested and the fresh weight obtained. The rhizomes included the entire rootstocks of the plants of all ages, but did not include the feeding roots. All material harvested was the growth of a single season. After harvest, the rootstocks were washed to remove dirt, and the feeding roots trimmed off and these and the bases of the stalks were discarded. The values in table 5 are the net weights of the cleaned material and represent what would be used in feeding animals or in the manufacture of starch. The weights of the tops were obtained by cutting the stalks at the surface of the soil and weighing the entire tops which included stalks and leaves of all ages. Data on four clones have been obtained, three belonging to the edible group and one to the ornamental group (table 5). There is a very great difference in yields of both tops and rhizomes. The Early Flowering No. 40 clone made the highest yield of rhizomes, amounting to 16.3 tons per acre in 1931. In the edible group, the Hawaiian clone made the poorest yield with 5 to 8 tons per acre, and the Java clone was intermediate. The yield of rhizomes of the ornamental variety Pennsylvania was less than that of any clone of the edible group except in 1930 when it exceeded the Hawaiian clone. In Hawaii, yields of 43.9 tons per acre have been reported for a 19-month period of growth. A yield of 16.3 tons per acre in 1 year, however, compares fairly favorably with the average results in Hawaii. However, the Hawaiian clone or the one generally used for starch manufacture there, yielded very poorly in these tests with results as low as 5.5 tons per acre. It may be concluded that climatic factors very greatly affect the behavior of different clones, and those suited to Hawaiian conditions may perform very poorly when grown elsewhere.

TABLE 5.—*Yield of rhizomes and tops of some forms of canna, 1930–32*

Part of plant	Year	Yield per acre of—			
		Hawaiian, P. I. No. 80386	Java, P. I. No. 80387	Early Flowering No. 40	Pennsylvania
		Tons	*Tons*	*Tons*	*Tons*
Rhizome	1930	5.5	7.4	15.6	6.2
	1931	7.9	8.8	16.3	4.3
	1932	7.2	9.1	13.6	6.8
Tops	1930	32.8	22.7	20.4	11.9
	1931	45.4	30.9	24.7	13.1
	1932	30.2	25.4	19.7	10.2

The yield of tops was greatest with the Hawaiian clone, which in 1931 made the very high yield of 45.4 tons per acre. Of the edible group the Early Flowering No. 40 clone gave the poorest yields, with values as low as 19.7 tons per acre. The ornamental variety Pennsylvania made the poorest yield of tops, with yields of 10 to 13 tons per acre. It should be stated, however, that the ornamental varieties started rather slowly in the field and the results obtained were probably far below those that might be obtained where the planting stock was started in a greenhouse. It is obvious from the data on yields of tops shown in table 5, and on the composition of the stalks and leaves shown in table 4, that very large yields of forage may be obtained per acre, and that the content of digestible nutrients compares very favorably with that of most forage crops. However, these studies have included no tests that would indicate the extent to which the material could be used in the daily ration.

It may be noted that in the edible group the clone that gave the greatest yield of tops made the poorest yield of rhizomes, and the one making the greatest yield of rhizomes made the poorest yield of tops. On the other hand, observations on a large number of seedlings indicate that forms making a poor growth of tops generally make a poor yield of rhizomes. In this locality, the Hawaiian clone, weather conditions being favorable, continued to grow the entire season without flowering, and the photosynthetic materials formed were used for vegetative growth rather than in the formation of large quantities of rhizomes with their reserves of carbohydrates.

The Early Flowering No. 40 clone made a moderate to good yield of tops and the plants flowered and set seed to some extent. In the latter part of the growing season, the plants formed a large number of rhizomes that were ideal for planting the following year. Much of the photosynthetic products formed was transported to the rhizomes which resulted in lessened yield of foliage but increased yield of rootstocks. The acid-hydrolyzable polysaccharides are somewhat less in this clone than in the Java, but the yield is very much greater, so that it is a much better producer of starch in this latitude than either of the other clones.

The yields of rootstocks and tops of the other clones grown in these tests were not obtained, but it was obvious that the yields of both rhizomes and tops were much smaller in the Russian clone than in either of the others. The Russian clone flowered very early and set large quantities of seed, but it was very much less vigorous than the other clones and therefore was inferior in nearly every way to the other clones.

It was also obvious that the seedlings of Early Flowering No. 40 varied greatly in yield of foliage and rhizomes as well as in color of foliage, height of plant, and earliness of flowering. Observations indicate that the rhizomes of Nos. 7, 11, and 31 yielded even better than the parent in 1933. Seedling No. 2 produced very large rhizomes, frequently becoming more than 4 inches in diameter. The total yield of rhizomes, however, was not so good as with the parent. The variations that occurred indicate that it may be possible by hybridization and selection to obtain forms making good yields of rhizomes of high starch content, which would be adaptable to growth in the milder parts of the temperate regions. The behavior in these tests of the clones of the edible group indicate that they may merit testing out as starch producers, at least in the lower border of the Gulf States.

COOKING TESTS

The characteristics that qualify or ban the canna rhizome as a table product have been given very little consideration by writers interested in the use of plant materials as food. The material is very unpalatable in the raw state; therefore, a few very simple cooking tests were made. For these tests rhizomes of a considerable number of clones were used, the tests being carried out immediately after digging the material in 1933. The rhizomes used were as nearly identical with those used in the analyses as was possible to determine. The old fibrous rootstocks were therefore not included. The rhizomes were trimmed, washed, and the outer layer of fibrous material removed. The rhizomes were then cut into cubes about one-half to three-fourths inch in diameter, again washed, placed in a dish, and heated in flowing steam for 30 minutes. They were salted to taste and after cooling were examined as to color, flavor, and texture. The ratings were given numerical values ranging from 1 to 5. A product of highest excellence was given a rating of 1, whereas the poorest product was given a rating of 5; other products were given intermediate values. The ratings were made by the writers and members of the immediate laboratory. The results are given in table 6.

TABLE 6.—*Comparative ratings of color, flavor, and texture of the cooked product of the rhizomes of some clones or varieties of canna*

Clone or variety	Color	Texture	Flavor	Clone or variety	Color	Texture	Flavor
Pennsylvania	4	4	5	Seedling No. 3	3	3	2
Nokomis	5	5	5	Seedling No. 4	2	3	3
Early Flowering No. 40	2	2	3	Seedling No. 5	3	3	2
Hawaiian	1	2	1	Seedling No. 7	3	3	4
Java	2	2	2	Seedling No. 10	2	1	2
Russian	5	5	3	Seedling No. 11	2	2	2
Seedling No. 1	3	2	3	Seedling No. 15	4	3	3
Seedling No. 2	1	1	1	Seedling No. 31	3	4	3

COLOR

In peeling and slicing the material it was noted that it turned brown very quickly in the air. Apparently the oxidase content was rather high and there were considerable quantities of oxidizable substances present. This brown discoloration could be largely prevented by immersing the material in 0.5-percent citric acid immediately after slicing. During and after cooking, there was a tendency in all the lots for the material to turn dark. This was much more pronounced in some varieties than in others. In the Russian clone and the ornamental varieties it was great enough to be distinctly objectionable, if not altogether too intense for the material to be acceptable as a table product. In the Hawaiian clone and in seedling No. 2 the tendency was not enough to be very objectionable. The other clones were rather similar to each other and intermediate in the degree of discoloration.

TEXTURE

During cooking the material softens to a starchy consistency agreeable to the palate, being a little firmer and less mealy than is ordinarily the case with potatoes and a little less firm than carrots. Lack of acceptable texture is due principally to the presence of fibers. There are vascular bundles extending through the rhizome which become less abundant and less tough towards the tip, finally disappearing completely a short distance back of the tip. Seedlings Nos. 2 and 10 were best in texture, with the Russian clone and the ornamental varieties the poorest. Generally, the short rhizomes of large diameter were the least fibrous and hence better in texture.

FLAVOR

The difference in the flavor of the various clones was generally not very great. However, the ornamental varieties were decidedly the poorest, and the Hawaiian clone and seedling No. 2 were somewhat preferable to the others. The flavor is not distinctly disagreeable nor yet is it very pleasing. To the taste the cooked product suggests a mixture of potatoes and Jerusalem-artichokes. It rather closely resembles the flavor of salsify, which suggests that it might be prepared and used in the same manner.

To test out this point, the rhizomes of the Early Flowering No. 40, the Hawaiian, the Java clones, and the rhizomes of Seedling No. 2 were washed, peeled, and cubed. The material was covered with 1-percent salt solution and boiled until tender at which time most of the solution had been evaporated or absorbed by the material. It was then prepared with white sauce in the manner frequently used in the preparation of salsify. It was evident that the material furnished an agreeable substitute for salsify but darkened more during cooking. Of the four clones tested, the Hawaiian and seedling No. 2 were slightly preferable and the Early Flowering No. 40 clone was the poorest. The principal differences were in the degree of discoloration and the texture.

CANNING TESTS

In order to study further the characteristics of the materials as food products, a few canning tests were made. These were carried out by washing, peeling, and cubing the rhizomes, which were then packed into No. 2 plain and enameled tin cans and the interspaces filled with hot 2-percent salt solution. The cans were exhausted 3 minutes, sealed, processed for 1 hour at 240° F., and then cooled in water. The Early Flowering No. 40, the Hawaiian, the Java clones, and seedling No. 2 were used. Some of the cans were opened the day following the processing and the color, flavor, and texture were noted. After 8 months in storage, other cans were opened and examined. A somewhat greater tendency to darken was observed in the canned than in fresh material prepared for the table, as previously described (p. 18). The flavor had been somewhat altered by the higher temperature used in processing, but as in the fresh material the flavor resembled that of salsify. The fibers in the material were a little more evident than was the case with the fresh material prepared with white sauce. The Hawaiian clone was slightly preferable to the others, and the Java was the poorest. It was concluded that the material would be acceptable as a table product to those who relish salsify. At the end of 8 months the plain tin cans had been considerably corroded, but very little action was noted on the enamel cans. The nitrates in the material were probably an important factor in the corrosion.

DISCUSSION

Composition of the rhizomes and the very great yields obtained from *Canna* indicate that it might be economically used as a source of carbohydrate in the ration. Certain characteristics of the tissues, however, together with the behavior in cooking and canning raise a doubt as to whether it should be considered of very great value as a table product. The rhizomes even of the ornamental types may be used as food and doubtless would be relished by those who like salsify. In the case of the ornamental varieties only a small part of the material at the tip of the rhizome appears to be suitable for table use. Because of differences in composition, behavior of the material during preparation, flavor, and other characteristics, the edible group is vastly superior to the ordinary ornamental varieties.

Nevertheless, even the edible group has three shortcomings from the standpoint of use as a table product. First, there is a tendency to darken in the air after peeling and slicing, which also prevails during and after cooking. This is apparently due to the astringent or tanninlike substances present that combine with iron compounds to form products that darken in the air. The formation of the dark-colored products from these constituents is also favored by the very low acidity. This discoloration can be largely prevented or minimized by the addition of small quantities of citric or acetic acid to the product before or during cooking.

The flavor, though not distinctly unappetizing, is not very appealing to the taste of many people. During the course of these tests the writers have eaten freely of the material to see if a taste for it would be acquired, but instead, a certain degree of aversion was developed. It appears much less desirable than the potato, but more nearly like salsify in flavor.

The fiber content is more or less objectionable. Though there are many vegetables that have an equal or greater fiber content, it is high as compared with the potato with which it would have to compete. The objectionable character of the fiber may be obviated partly by peeling the material and slicing the rhizomes transversely, cutting the fibers into short bits, but it is doubtful if it would ever be considered an equal to the potato.

The yields of certain types in this locality seem sufficiently high to justify more extensive tests in the southern border of the Gulf States where the longer growing season would doubtless be better suited to the production of material of high starch content.

SUMMARY

The composition of the rhizome of the canna plant as grown near Washington, D. C., varied considerably from season to season in any given variety. There was also a wide range of difference in composition in different forms. Conditions that favored a high solids and polysaccharide content appear to be an abundant rainfall during July and August, followed by a moderate rainfall in September and October. On the other hand, dry conditions during July and August followed by excessive rainfall in September and October seem to favor a low content of solids and polysaccharides. The influence of weather is probably accounted for through the control exerted over the degree of maturity of the rhizomes at the end of the season.

The variations in composition and yield in different clones and seedlings of the edible group indicate possibilities of selecting types that are adapted to growth in particular localities and which produce good crops of rhizomes of high starch content.

The rhizomes of the ornamental or flowering varieties differed in their composition from types of *Canna edulis* in having considerably higher tannin content and a somewhat higher content of total nitrogen, nitrate nitrogen, and acidity. The fiber content was also higher in the garden forms.

The composition of different parts of the plants of the edible group varied very greatly. The leaves were high in total solids, total nitrogen, and total astringency but low in sugars, acids, and nitrate nitrogen. The stalk or stem was low in total solids and total nitrogen, but comparatively high in sugar and nitrate nitrogen. The rhizomes were comparatively high though variable in solids and polysaccharides but low in sugars, total nitrogen, and acidity. The apical or growing end of the rhizome was lower in solids, polysaccharides, total sugars, and nitrate nitrogen, but higher in total nitrogen and acidity than the more mature basal end. The young leaves were higher in total nitrogen, acidity, solids, and total astringency, but lower in nitrate nitrogen and reducing sugars than the old or basal leaves. The base of the stalk was lower in total solids, acidity, acid-hydrolyzable polysaccharides, and astringency, but higher in sugar and nitrate nitrogen than the upper portion.

The yield of rhizomes and tops varied very greatly with different clones. Yields as high as 16 tons of rhizomes and 45 tons of tops per acre have been produced, whereas results as low as 5.5 tons of rhizomes and 19.7 tons of tops per acre were obtained with certain clones of the edible group. The production of a large amount of tops was not always accompanied by a corresponding production of rhizomes. Also, there seemed to be little relationship between yield and composition of the rhizomes.

Cooking and canning tests indicate that the rhizomes may be used as a table product, but the material possesses certain characteristics making it more or less undesirable for this purpose. Among these may be mentioned the tendency of the material to discolor during preparation and cooking and the presence of fibrous structures in the tissues. The flavor resembles very much that of salsify and the table product would probably be acceptable to those who relish this vegetable. Different clones varied considerably in the degree of discoloration, the fiber content and the flavor, each of which influences the table product, so that some types were much preferred to others.

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